Gaulocrinus trautscholdi (Wachsmuth and Springer), n. comb.

Stemmatocrinus trautscholdi Wachsmuth and Springer, 1885, pl. 9, figs. 7, 8; 1886, p. 256 (180): "Keokuk limestone near Nashville (White's Creek), Tenn."

Gaulocrinus veryi (Rowley), n. comb.

Stemmatocrinus? veryi Rowley, 1903, p. 133, pl. 38, figs. 7, 8: " . . . probably Keokuk group, of Cumberland County, Kentucky."

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BOTANY.—*Notes on four eastern species of* Gymnosporangium.[1]

W. H. Long, Albuquerque, N. Mex. (Communicated by John A. Stevenson.)

This paper reports investigations conducted in 1912 and 1913 in the District of Columbia and vicinity, while the author was in the employ of the U. S. Division of Forest Pathology, on the occurrence of four species of *Gymnosporangium, G. clavipes* Cke. & Pk., *G. nidus-avis* Thaxt., *G. effusum* Kern, and *G. juniperi-virginianae* Schw.; on the lesions produced by them on the eastern red cedar (*Juniperus virginiana* L.); and on inoculations made with *G. effusum.*

The purpose of these studies was to determine what species of *Gymnosporangium* occurred in the District of Columbia and adjacent areas, their prevalence and distribution, their action on the host, and to ascertain, if possible, the aecial stage of *G. effusum.*

More than 3,000 red cedars were examined for the presence of *Gymnosporangia,* and a record was made of the distribution on each tree of the species found. Data were taken on the extent and character of the lesions produced. Record for each tree was maintained on an individual card showing size and condition of tree, number of lesions on trunk and branches for each species of rust, nature and size of each lesion, and any other pertinent data, such as nearness to aecial hosts if any, for each locality studied. Table 1 gives a summation of these data, showing number of trees examined, number infected, and number of trunk and branch lesions found for each of the four species of *Gymnosporangium.*

The investigations were made during the months of April and May, as the lesions are most conspicuous during these months because of the swelling and gelatinization of the telia. April was very rainy in 1912, with intermittent showers and often with mists and fogs making ideal conditions for the maturation and gelatinization of the telia.

Three of these species of *Gymnosporangium* are perennial in the red cedar while the fourth is biennial. The prevalence of each species for any given area can be determined from the telial stage more accurately than from the aecial since the former is not dependent for its appearance on the climatic factors for each season. A dry year would reduce very materially the aecial stage for that year, but would not affect to any great extent the perennial lesions in the telial hosts.

[1] Received March 9, 1945.

A study of the table shows that 3,040 red cedars were examined, of which 1,206 were attacked by *Gymnosporangium clavipes*, 382 by *G. nidus-avis*, 165 by *G. effusum*, and 76 by *G. juniperi-virginianae*. *G. clavipes* headed the list with 17,030 lesions, *G. nidus-avis* had 1,650, *G. effusum* 408, and *G. juniperi-virginianae* 897, making a total of 19,985 lesions for the four species.

Gymnosporangium clavipes

This species was widely distributed over the areas investigated and was the most abundant as to number of cedars infected and lesions produced. The older and larger cedars were the most heavily infected (see Table 1 for Arlington Cemetery and Catholic University). None of the areas examined was free of this rust, but in some localities it was rare.

G. clavipes was rarely abundant on trees with open tops or with the lower limbs removed for one-half of the distance up the tree, or, strange to say, on solitary trees in the open with many small branches down to the ground. The trees of the last group have a close, dense growth, and this was especially true for trees 2 to 6 inches in diameter. When *G. clavipes* was sparingly present, *G. nidus-avis* and *G. effusum* were usually absent. Cedars that did not have trunk lesions of *G. clavipes* were often so situated that their trunks were not shaded much and had very open foliage. Apparently most of the trunk lesions originated directly on the trunk and did not start on a small branch or twig and thence work down along the trunk.

This rust traveled more rapidly laterally than longitudinally and did not kill the living bark even in the center of the oldest and largest lesions on trunks and large branches, but killed small branches and twigs by girdling and sapping them of their vitality. The yellowish-red telia were small and inconspicuous under the old dead bark of the trunk and were irregularly scattered over the surface of the lesions. All these were well-marked characters of this rust. No lesions were found on very young twigs, but all were on those with well-developed wood and without needles.

Many trunk lesions were found which apparently originated in the enlarged wood at the base of a branch protected by the loose bark at that point. Such lesions did not originate on the branch proper but at its juncture with the trunk and spread from there to the trunk. One of the largest trunk lesions found was 90 cm wide by 40 cm long, with the outer bark very thick, rough, and blackish over the lesion, which was alive throughout. There were numerous trunk lesions on this tree, but there was no evidence that any of them started from branches and then spread to the trunk.

Gymnosporangium clavipes is well recognized as a serious rust on certain varieties of apples, and the abundance of this species over the areas here reported indicates that it would become a serious menace to apple culture during favorable years in these regions.

Gymnosporangium nidus-avis

This *Gymnosporangium* was also found widely distributed over the areas investigated, coming next to *G. clavipes* in number of cedars, infected and lesions produced. Only one area, Park Lane, Va., was free from this species, possibly owing to the small size and youth of the cedars, which were only half an inch to 2 inches in diameter.

Arlington Cemetery and Great Falls, Va., were the most heavily infected areas both in number of trees attacked (301) and lesions (1,418) produced. This heavy infection probably was due to the size of the cedars involved (2 to 45 inches in diameter) and the extreme age of many of them. This rust produces three types of lesions—trunk, branch, and broom. One hundred out of 1,108 branch lesions and 186 of 483 brooms were dead.

The open type of broom with normal needles found about Washington was quite different in aspect and much larger than the dense brooms with juvenile needles found on *Juniperus virginiana* L. var. *crebra* Fernald & Griscom from Massachusetts. In the material examined from Washington and vicinity no telia or lesions were found on young twigs or among the needles, but they were confined to the limbs and branches with heartwood. The living bark down to the sapwood under and adjacent to the telia was stained a golden-yellow during the maturation and gelatinization period. This was a very marked character by means of which the infected area could often be determined even before the telia were formed. This yellow color was due to small yellowish globules in the rust

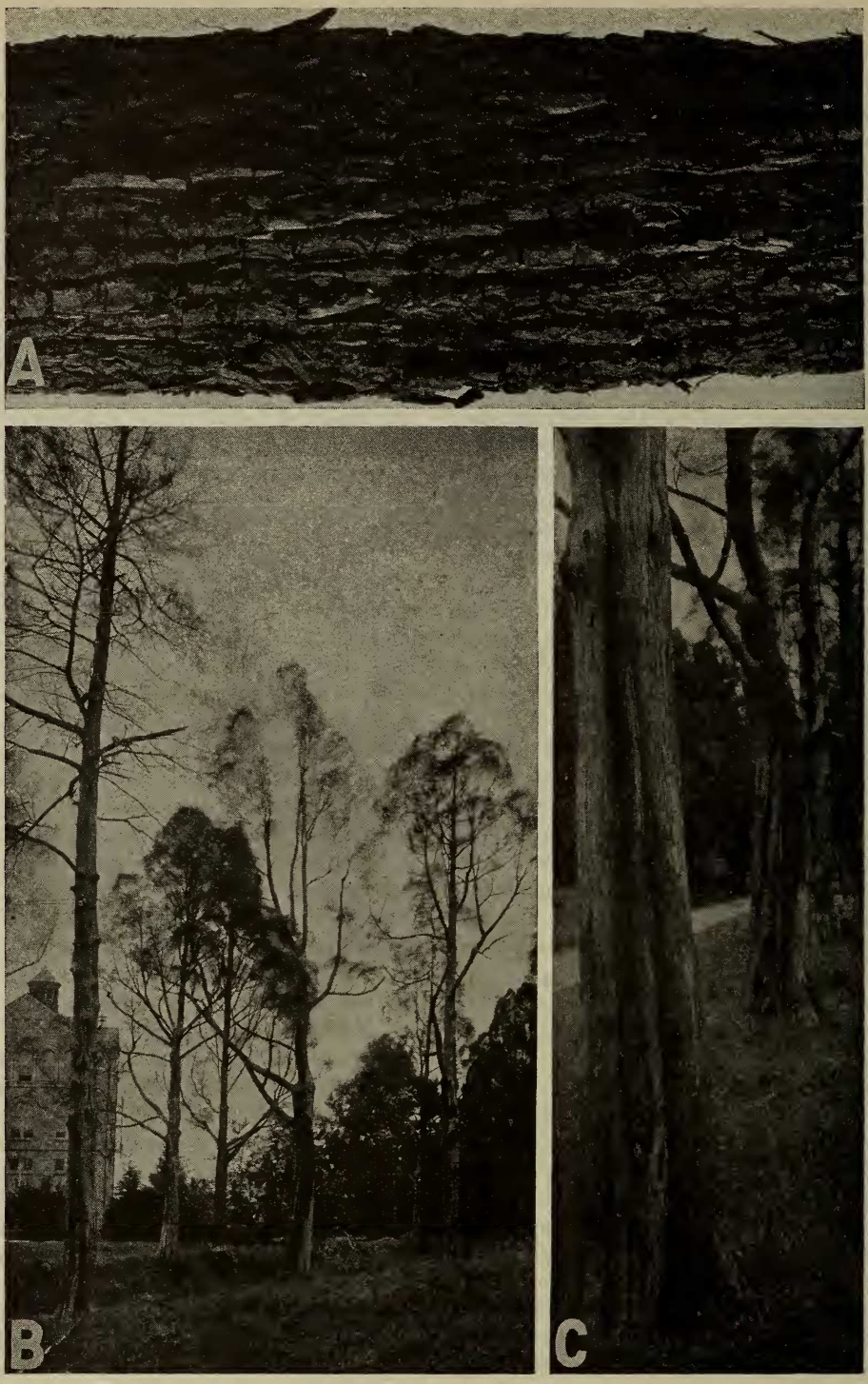

FIG. 1.—*A*, A typical branch lesion of *Gymnosporangium effusum* with its ridgelike galls extending in parallel lines on the diseased area; *B*, a row of red cedars on the grounds of the Catholic University of America at Washington, D. C., dying from the attacks of three species of *Gymnosporangium*, especially *G. effusum*. Note how many lower branches have died and been removed, and the large black trunk lesions due to *G. effusum; C*, closeup view showing more clearly the lesions. Through the kindness of the University authorities, the writer learned that all the trees shown in this figure were dead by 1927, except one which, though still alive, has much dead wood on it.

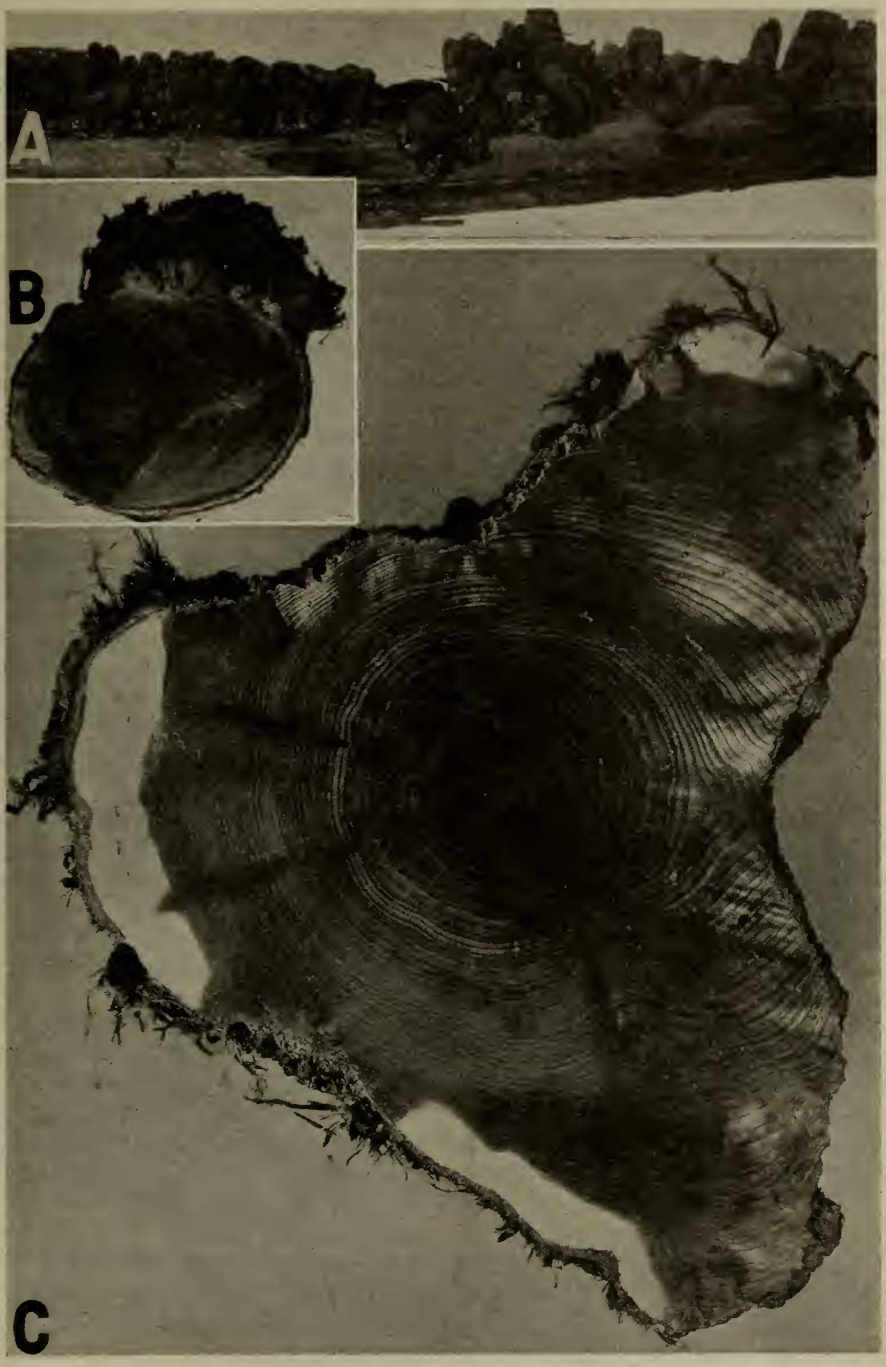

FIG. 2.—*A*, A row of living expanded telia of *G. effusum; B*, cross section of a living gall of *G. effusum* with expanded telia, showing the deep seated character of the lesion; *C*, cross section of a red cedar with three major trunk lesions of *G. effusum*, which have practically killed the tree.

hyphae, which occur in the subhymenial layers beneath the telia. In addition to these yellow globules, many suppressed but apparently mature golden-yellow spores were present, but these were not the main cause of the yellow color. In the Sharon, Mass., material of *G. nidus-avis* no yellow color was found in the substratum beneath the telia.

Some of the brooms around Washington, D. C., were very large, being 58 cm long by 77 cm wide, while trunk lesions ranged from 70 cm long by 9 cm wide to 175 cm long by 42 cm wide. One large branch lesion was 350 cm long on a branch 9 cm in diameter, entirely girdling the dying branch for most of its length.

The material of the dense juvenile-needle brooms studied was obtained from Sharon, Mass., through the kindness of the late Dr. Farlow, while the open type of brooms here discussed was found in the District of Columbia and vicinity.

Gymnosporangium effusum

This species was described by Kern (*5*, pp. 459–460) from material collected by him on the Santee Canal in South Carolina in 1909, but since then very little of importance has appeared in print concerning this *Gymnosporangium*.

Lesions of this rust formed deep-seated, woody-corky, truncate, ridgelike galls, which ran longitudinally in parallel rows on branches and trunks of the red cedar. These galls were 2 to 6 mm tall by 3 to 12 mm wide, with "roots" penetrating to the sapwood of the host (Fig. 2B). These ridgelike galls when alive were composed of rather firm cheeselike tissue filled with rich foodstuffs for the development of the telia. After the teliospores matured the galls became brown, more or less suberized, and covered with a corky callus. After one or possibly two years of fruiting these galls died but persisted for years on the old dead areas of the lesions. These ridgelike galls usually checked transversely into pieces 2 to 15 mm long (Fig. 1A).

The infection spread very slowly transversely on the branches and trunks and the new galls developed at irregular intervals next to and on the outside of the old ones and parallel with them. The telia appeared longitudinally in the ridgelike galls, breaking through the surface callus in slits with only one row of flattened telia to each gall. When expanded the telia were wedge-shaped (Fig. 2A), 10 to 12 mm tall by 2 to 6 mm thick at the top by 10 to 30 mm long, often with ends of the telia confluent for 4 to 6 cm, rugose to dentate on top, sometimes tongue-shaped to cristate, as thick at the bottom as at the top or even thicker, rather firm when fully expanded and often falling away in a body leaving a yellowish scar. The fallen telia had a longitudinal slit extending up into their bases for 1 to 2 mm. Telia when expanded were a light watery brown and about one-third to one-half taller than before gelatinization.

Successive years of fruiting on twigs and branches finally killed the lesions by the complete destruction of the cortex, phloem, and cambium. The old galls became dark brown to blackish with age. The surface of the old lesion on the trunk was usually in a depression covered with the corky ridges of the dead lesions. Very old dead lesions had a charred look like a fire scar (Figs. 1B and 1C) caused by the transverse cracking of the corky ridges and the darkening and partial falling out of the cubes of the diseased dead tissue from weathering.

The trunk lesions gradually killed the live wood, and as these lesions extended very slowly transversely the fungus formed a depression in the trunk, which widened as the tree grew until often only a small amount of live wood tissue was left to nourish the tree (Fig. 2C). The tree was finally killed.

Fig. 2C is a fine example of the action of this *Gymnosporangium* on the tree trunk. This cross section shows three large lesions, which through the years gradually killed nearly all the living tissue of the trunk. One of these lesions was 80 years old, the fungus having entered when the tree was 33 years old. The cross section of another trunk showed a 108-year-old lesion that started when the tree was 20 years old. The fungus at the edges of the lesion, by progressive growth in the adjacent wood, prevented any wound callus from forming, thereby keeping the wound open as shown in Fig. 2C, where the small amount of wood still alive can be noted.

The longitudinal growth of the rust lesion ranged from a maximum of 3 inches to a mini-

mum of 1 inch, having an average of 1.5 inches per year with very little appreciable increase in width. No very young lesions were found, the youngest being 72 cm long by 3½ cm wide. It apparently started on the trunk since no limb was near. Many trunks of red cedars had lesions that were largest at the ground line, then tapered upward, as if the lesion started at or very near the ground. Many branches had been killed by being engulfed and surrounded by adjacent trunk lesions. These dead branches were free of any infection above their bases; hence they could only have been killed by being engulfed. Branches were often flattened by lesions, many of which started on the underside.

This is one of the few rusts in which the length of time the rust has been in the tree can be determined, due to the nature of the lesions that it produces. Trees were found that had been infected for 108 years or longer. Trunk lesions ranged from 22 to 1,050 cm long and of those studied 40 were dead. The number of trunk lesions ranged from 0 to 6 per tree. Branch lesions totaled 173, ranging in length from 15 to 425 cm, and of these 37 were dead.

This is the only *Gymnosporangium* so far as is known that kills the cortex, phloem, and cambium down to the xylem. No study was made on how this killing occurred or the method of lateral spread in the host.

Dodge (*4*) discusses the damage done to *Juniperus virginiana* by *G. nidus-avis*. He divides the lesions produced into two types, the effuse and the caulicolous forms, and on page 106, figure 3, gives photographs of the two types of lesions. His figure 3, A, is a good representation of the caulicolous type of lesions produced by *G. nidus-avis*, showing the irregular orientation of the telia on the lesion, while figures 3, B, and 3, G, given as the effuse form of the above species, are typical examples of the lesions produed by *G. effusum*.

Crowell (*3*, p. 473) claims that *G. effusum* and *G. nidus-avis* are the same species as determined from cultures and microscopic studies of the two species. Apparently the data given and the inoculations made by him were based on the caulicolous form of *G. nidus-avis*. The highly characteristic lesions produced by *G. effusum*, so different from any other *Gymnosporangium*, should make it impossible for this species to be confused with any other.

The alternate stage of *G. effusum* has never been positively determined. Arthur (*1*) reported inoculations made in 1911 on *Aronia arbutifolia*, *Amelanchier canadensis*, *Pyrus communis*, *Malus coronaria*, and *Malus malus*. These sowings produced pycnia on *Aronia artibutifolia* but no aecia ever developed and there was no infection on any of the other hosts inoculated. Arthur (*2*, p. 371) made only one set of cultures of this *Gymnosporangium*. During April and May 1912, the writer made sowings with *G. effusum* from *J. virginiana* on the following species of hosts:

Aronia arbutifolia—10 plants, April 19, 1912, and 5 plants, May 8, 1912.

Aronia nigra—4 plants, April 19, 1912; 2 plants, April 29, 1912; and 2 plants, May 8, 1912.

Amelanchier canadensis—4 plants, April 19 and 29 and May 8, 1912.

Chaenomeles japonica—2 plants, April 10 and 19, 1912.

Cydonia vulgaris—2 plants, April 10 and 19, 1912.

Malus coronaria—3 plants, April 10 and 22, 1912.

Malus malus—2 plants, April 10, 1912.

Pyrus communis—2 plants, April 10 and 19, 1912.

Cerasus arbutifolia—1 plant, April 10, 1912.

No infections developed from any of these sowings.

Recently the writer noted that there are only two species of *Gymnosporangium* whose alternate stages are unknown, *G. effusum* for the aecial and *G. hyalinum* for the telial stage. The type locality of both is South Carolina, and the range of each is much the same along the southern Atlantic coast. There is, therefore, a strong probability that the aecial host of *G. effusum* is one or more of the species of *Crataegus* listed for *G. hyalinum*, viz., *C. clara* Beadle, *C. dispar* Beadle, *C. egens* Beadle, *C. egregia* Beadle, *C. michauxii* Pers., *C. munda* Beadle, *C. pexa* Beadle, *C. quasita* Beadle, *C. viridis* L., and *C. visenda* Beadle. It is rather strange that no one so far as known has made sowings of *G. effusum* on any of these or other species of *Crataegus*. *G. trachysorum*, a closely related species, has its aecial stage on *Crataegus*, which is another indication that this host may contain the aecial stage of *G. effusum*.

Gymnosporangium juniperi-virginianae

This species was not very abundant over the

areas investigated. Only areas with young and small cedars had any appreciable number of trees attacked by it; on those areas where the trees were old and large very few or none were infected. In Arlington Cemetery three galls were found, and only one of these was alive. It seems odd that so few trees of the more than 3,000 examined were infected with this *Gymnosporangium*, which is in marked contrast to the large number attacked by *G. clavipes*. Dead galls as well as living ones were counted, and yet the number found was very small, as shown in the table.

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Table 1.—Data on Gymnosporangium Lesions on Juniperus virginiana for Each Area Investigated[1]

Location and diameter of trees	Trees examined	*G. clavipes*			*G. nidus-avis*				*G. effusum*			*G. juniperi-virginianae*		
		Trees infected	Lesions		Trees infected	Lesions			Trees infected	Lesions		Trees infected	Lesions galls	Total lesions
			Trunk	Branch		Trunk	Branch	Brooms		Trunk	Branch			
Arlington Cemetery, 2–45″	555	545	1,730	6,580	169	33	545	433	97	100	89	3	3	9,513
Catholic Univ., 4–28″	93	75	434	1,006	12	4	12	1	33	107	56	0	0	1,620
Roads near Catholic Univ., 16–32″	76	44	40	275	15	1	28	1	22	19	22	0	0	386
Great Falls, Va., 2–6″	405	403	1,697	4,050	132	16	356	45	7	5	2	2	15	6,186
Park Lane, Va., ½–2″	383	4	0	20	0	0	0	0	0	0	0	0	0	20
Fences near Park Lane, 4–12″	388	29	32	119	10	3	33	0	0	0	0	6	63	250
Franklin Park, 2–14″	174	14	42	70	3	0	10	0	0	0	0	36	615	737
Country Club, 4–20″	116	30	200	464	11	1	35	0	0	0	0	1	20	720
El Nido to Franklin Park, 6–14″	49	40	60	115	2	0	4	0	1	0	1	6	40	220
Fence rows, 3–16″	503	7	0	33	14	0	43	4	1	0	1	22	141	222
Scattered trees, 6–12″	298	15	3	60	14	0	42	0	4	4	2	0	0	111
Totals	3,040	1,206	4,238	12,792	382	58	1,108	484	165	235	173	76	897	19,985

[1] Many of the cedars in Arlington Cemetery were being seriously damaged in 1912 by three other enemies in addition to the rusts: a climbing grape vine (*Vitis* sp.) had overrun 75 of them, killing 38; 51 of the trees had poison-ivy (*Rhus toxicodendron*) on trunks and lower branches; while 102 had a butt rot (*Fomes subroseus*), which was destroying the heartwood, thereby weakening the trees.